MEASUREMENT TECHNOLOGIES

THIRD QUARTER QUALITY ASSURANCE REPORT
FOR
TRUE GEOTHERMAL ENERGY COMPANY MONITORING PROGRAM
KILAUEA MIDDLE EAST RIFT ZONE, ISLAND OF HAWAII

Submitted to:

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2.0 Monitoring Network Description

The monitoring network consists of two monitoring stations located approximately 7 miles west of Pahoa, Hawaii. The primary monitoring site is designated as "Site 1 Air Quality/Met." This site is located in the Kaohe Homesteads near the end of Kaohe Homesteads Road in a large 5 acre residential home lot. The second monitoring site is designated as "Site 2 MET". This site is located at the Drilling site 1. The monitoring stations and parameters monitored are identified in Table 2-1.

Table 2-1. Parameters Monitored

PARAMETER	SITE 1	SITE 2
SULFUR DIOXIDE (SO_2)	X	
HYDROGEN SULFIDE (H_2S)	X	8 PLS
WIND DIRECTION	X	X
WIND SPEED	X	X
VERTICAL WIND SPEED		X
SIGMA THETA	X	X
SIGMA W		X
TEMPERATURE	X	
PRECIPITATION	X	
RAIN WATER (ANIONS & DISSOLVED METALS)	3 PLS	
METALS (ATMOSPHERIC PARTICULATE)	X	
TOTAL SUSPENDED PARTICULATES (TSP)	X	
INHALEABLE PARTICULATES (PM-10)	X	
RADON		X

2.1 Site 1 Air Quality/Met

The monitoring station is located 800 feet north of a residence, in an open field approximately 400 by 600 feet in area. A portable shelter houses the aerometric analyzers and data acquisition equipment. The meteorological equipment is mounted on a 10 meter retractable tower attached to the south side of the shelter. A heated stainless steel intake manifold for the SO_2 and H_2S analyzers extends one meter above the roof. The integrated sampler and particulate samplers (PM-10 and TSP) are located on a wooden platform about 30 feet west of the monitoring shelter. The inlets to the particulate samplers are 1 meter above the ground. The inlet to the integrated sampler is 1.5 meters above the ground. The air quality station obtains electrical power from one of two propane generators housed in a small building about 150 feet west of the monitoring station.

The three plastic rain gages for collection of rainwater samples are located in the Kaohe Homestead area on residential properties along Kaohe Homesteads Road. The first rain gage is located next to the particulate platform at the monitoring station. The second gage is located at a residential lot about 1,200 feet northeast of the station. The third rain gage is located at a large commercial horticulture farm about 1,200 feet to the northeast of the second rain gage site. The tipping bucket precipitation gage for continuous collection of real time data is located on the monitoring shelter roof.

Sulfur dioxide and hydrogen sulfide is measured using Meloy Laboratories flame photometric analyzers. Wind speed and wind direction are monitored with the Met One model 014 three-cup anemometer and the Met One model 024 light weight air foil wind direction sensor. Temperature is measured with a Met One model 060 temperature sensor mounted in a Met One naturally aspirated radiation shield. Precipitation is measured with a Weathertronics 6010 tipping bucket rain gage.

Data acquisition is performed by an Odessa Engineering DSM 3260 air quality/meteorological data acquisition-system (DSM). The DSM retrieves, processes, and stores the collected data on a solid state data cartridge. The cartridge is backed up by a printed hardcopy using a Star NX1000 dot matrix-printer. The data stored on the cartridge are retrieved by removing the cartridge and forwarding it to Measurement Technologie's office in San Luis Obispo, California. The data is stored and processed on an IBM-AT compatible computer system equipped with a data management software package.

The air quality station is equipped with a Radian RAD III gas dilution calibrator which provides the precise gas concentrations to perform daily Level 2 checks, multipoint calibrations, Level 1 and precision checks on the sulfur dioxide and hydrogen sulfide analyzers.

2.2 Site 2 MET

The meteorological station is located at Drilling site D-1. Meteorological sensors are located atop a 10 meter retractable tower, located at the edge of the large water storage pond. A NEMA 4 enclosure is mounted at the base of the tower to house an Odessa DSM 3260/MET system, charger and battery. A solar panel is mounted on the tower to supply power for the DSM, meteorological sensors and charge the battery.

Eight passive hydrogen sulfide dosimeter badges are placed on fence posts located along the perimeter of the drilling site. These badges are located to the N, NE, E, SE, S, SW, W and NW perimeter of the drilling area. A Radon detector is located south of the drilling platform.

Wind speed and wind direction are monitored with a Weathermeasure model W203 three-cup anemometer, and a Weathermeasure model W204 air foil wind direction sensor.

Vertical wind speed is monitored with a R. M. Young Gill propeller anemometer.

The data acquisition is handled by an Odessa Engineering DSM 3260 meteorological data acquisition system (DSM). The DSM retrieves, processes, and stores the data on a solid state data cartridge. The data stored on the cartridge are retrieved and stored identically to site 1 (Air Quality / Met) data.

3.0. Performance Audit Procedures and Equipment Description

3.1. Audit Procedures

3.1.1. Sulfur Dioxide, Hydrogen Sulfide

The sulfur dioxide and hydrogen sulfide analyzers were audited by producing four upscale gas concentrations plus zero by diluting National Institute of Techonology (NIST) traceable standard gases with zero air. This is done using an audit calibrator equipped with mass flow controllers.

Audit concentrations are introduced into each analyzer upstream of the sample filters and lines (through as much of the sample train as practical). Each analyzer is allowed to sample each audit concentration until a stable response is obtained. The analyzer responses are observed by keying the data acquisition system to provide 5-minute averages. In addition the efficiency of the SO_x scrubber on the H_2S analyzer is tested by introducing an upscale SO_2 concentration to the analyzer, and noting its response. The gas ranges used to conduct the audits are presented in Table 3-1.

Table 3-1. Audit Gas Ranges

Range ppb
0
30 - 80
150 - 200
250 - 350
350 - 450

3.1.2 Wind Direction

A portable field compass is used to determine the accuracy orientation of the wind vane. This is done by measuring the azimuth of the crossarm. A correction of + 11^{o} is made for the magnetic declination. The vane accuracy is then tested by holding the wind vane parallel to the crossarm and noting the DSM response. The linearity of the sensor is checked by holding the wind vane at the four cardinal points.

3.1.3 Wind Speed

The wind speed sensor at both sites is tested by connecting 60 and 300 revolution per minute (RPM) continuous speed synchronous motors to the sensor shaft. The manufacturer's algorithm is used to convert RPM to miles per hour (MPH) and the result is compared to the DSM output.

3.1.4 Temperature

The temperature sensor is checked by collocation with an NIST-traceable thermometer. The thermometer reading is corrected to true temperature and is compared to the temperature output on the DSM.

3.1.5 Precipitation

The precipitation gauge is audited by adding a known volume of water. The gauge inlet is 8" in diameter and one tip represents 0.01" of precipitation. According to the manufacturer's specifications, if 80 cc of water is slowly added to the gauge, the bucket should tip 10 times. This should result in the DSM output of 0.10" of precipitation.

3.1.6 Particulate Sampler

The samplers are audited using the procedures described in The Quality Assurance Handbook for Air Pollution Measurement Systems, Section 2.2.8.1 (January, 1983), and Section 2.0.12.11 (June, 1984). The procedure consists of placing an audit orifice on each sampler inlet with a sample filter in place. The sampler is then turned on and allowed to warm up for about five minutes. After warm up, the following data are recorded:

- Orifice pressure drop in inches of water;
- Ambient temperature and barometric pressure;
- Indicated station sampler flow as read by the sampler chart recorder.

The audit flow is then calculated using the orifice calibration. The TSP sampler flow is calculated in standard conditions and the PM-10 sampler flow is calculated in ambient conditions. The values are compared to their respective station flows as a percent difference. In addition the PM-10 flow under normal sampling conditions is evaluated with respect to its deviation in percent difference from the ideal design flow of 40 ACFM.

3.1.7 Integrated Sampler

The integrated sampler is audited by measuring the flows at several points with a certified mass flow meter. The measured flows are then compared with the indicated station flows per the calibration curve for the sampler, and the results are presented in percent difference.

3.1.8 Station Evaluation

A checklist is completed as part of the systems audit at each monitoring station. Copies of the checklists are presented in Appendix B.

3.2 Audit Equipment Description

3.2.1 Audit Calibrator

The audit calibrator used to conduct the audits of the air quality analyzers is a ABB Environmental mass flow controlled dynamic gas dilution calibrator. The calibrator contains a 10,000 sccm dilution mass flow controller and a 50 sccm span gas mass flow controller. The calibrator produces precise concentrations by diluting high level gas standards with zero air, which is produced by a clean air system to remove all concerned compounds from the dilution and air. The clean air system consists of silica gel to dry the ambient air, an ultraviolet source to irradiate the dry air to convert any nitric oxide (NO) present to nitrogen dioxide (NO_2). After the air is irradiated it is passed through packed activated charcoal and Purafil columns to remove any ozone, sulfur dioxide, hydrogen sulfide, and ammonia present in the air.

The calibrator flow rates are measured prior to and after the audit using an NIST traceable Hastings bubble flowmeter and Brooks Volume meter. The auditor uses a bubblemeter in the field to verify flows if there is any indication that an audit flow is incorrect.

3.2.2 Wind Speed Motors

Two R.M. Young continuous speed synchronous motors are used to audit the wind speed sensors. One motor operates at 60 RPM and the other at 300 RPM. These motors are tested once a year for accuracy by the manufacturers.

3.2.3 Miscellaneous Audit Equipment

A NIST traceable thermometer is used for auditing the temperature sensor. The barometer used for the particulate sampler audits is verified by comparison with a mercury barometer before and after the audit. A Brunton compass is used for determining the orientation of the wind direction crossarm. A General Metals Works orifice kit is used to perform flow rate audits of the particulate samplers.

4.0 Audit Standards Verification

Where applicable each audit standard is verified or certified using the appropriate methods specified in the applicable EPA guidelines.

4.1 Gas Standards

Two gas standards are used for the audit. The cylinder containing sulfur dioxide (SO_2) was certified by ABB Environmental using EPA Protocol No. 2 by ABB Enviromental. Protocol No. 2, requires a direct comparison between the audit gas and NIST Standard Reference Material (SRM). This traceability protocol is contained in EPA-600/4-77-027a, Quality Assurance Handbook for Air Pollution Measurement Systems, Vol II, Section 2.0.7.

The cylinder containing hydrogen sulfide (H_2S) was certified by ABB Environmental using a gravemetrically-certified permeation tube. There is currently no EPA protocol for hydrogen sulfide gas.

4.2 Audit Calibrator

The audit calibrator is a ABB Environmental mass flow controlled dynamic gas dilution calibrator. The calibrator was previously described in Section 3.2.1. Audit flow rates are measured before and after the audit using an NIST traceable Hastings bubble flowmeter and a Brooks Volume Meter.

4.3 Particulate Sampler Audit Equipment

A General Metal Works orifice is used for auditing the PM-10 and TSP samplers. The orifice is checked annually against an NIST traceable roots meter. The integrated sampler is audited with a mass flow meter, certified by ABB Environmental.

4.4 Meteorological Audit Equipment

A NIST traceable thermometer is used for auditing the temperature sensor. Synchronous motors used for auditing the windspeed sensors are tested for accuracy on an annual basis by R.M. Young Company. The compass used for the wind vane calibration test is periodically checked against other compasses and/or other siting techniques.

5.0 Audit Criteria and Results

5.1 Audit Criteria For Ambient Air Quality Analyzers

The EPA-recommended audit criteria for aerometric analyzers used in the measurement of criteria pollutants is presented in Table 5-1. These criteria are taken from EPA-600/4-77-027a, Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. II, May, 1977.

Table 5-1. Analyzer Audit Accuracy Specifications

Slope	
Excellent	$\leq \pm 5\%$ between analyzer response and audit concentration
Satisfactory	$\pm 6\%$ to $\pm 15\%$ between analyzer response and audit concentration
Unsatisfactory	$> \pm 15\%$ between analyzer response and audit concentration
Intercept	
Satisfactory	$\leq \pm 3\%$ of the analyzer range
Unsatisfactory	$\geq \pm 3\%$ of the analyzer range
Correlation Coefficient	
Satisfactory	0.9950 to 1.000
Unsatisfactory	< 0.9950

5.2 Audit Criteria For Meteorological Instruments

The EPA recommended audit criteria for meteorological instruments is presented in Table 5-2. These criteria are taken from EPA-600/4-82-060, Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. IV, Meteorological Measurements, February, 1983.

Table 5-2. Meteorological Audit Accuracy Specifications

Parameter	Tolerance
Wind speed[1]	±0.2m/s (< 5m/s) ±5% (> 5m/s)
Wind direction[2]	±2°
Temperature	±0.25°C
Precipitation	±0.01"

1 This criteria was adjusted to be consistent with the accuracy specifications for wind speed sensors in EPA-450/4-007, Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), May 1987.

2 This criteria is an accuracy criteria which only applies to the accuracy of the audit point where the sensor is aligned with the crossarm. The linearity criteria used by ABB Environmental is ± 3° which conforms with the accuracy specification for wind direction sensors in the PSD guidelines.

5.3 Audit Criteria For Particulate & Integrated Sampler

The EPA recommended audit criteria for particulate and integrated samplers is ± 7 % difference between the audit flow and actual flow rate. The PM-10 sampler is also audited for its operational flow's deviation from 40 ACFM. The acceptable accuracy is ± 10%.

5.4 Audit Results

Completed audit data sheets for each audit parameter are presented in Appendix A. All aerometric analyzers and meteorological equipment demonstrated satisfactory results. Completed station inspection checklist are presented in Appendix B.

5.4.1 Ambient Air Quality Analyzers

The SO_2 and the H_2S analyzers demonstrated satisfactory results to the audit tests.

5.4.2 Meteorological Equipment Audit Results

All meteorological sensors demonstrated satisfactory results to the audit tests.

5.4.3 Particulate & Integrated Samplers

The particulate and integrated samplers demonstrated satisfactory results to the audit tests.

APPENDIX A

H_2S AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: Air Quality, Site 1 AUDITOR: David Gemmill

ANALYZER MFR: Meloy Labs CALIBRATOR MFR: ABB Environmental

MODEL NUMBER: SA285E CALIBRATOR S/N: 5

ANALYZER S/N: 7E033

AUDIT GAS CYL. NO: CAL 6141 AUDIT GAS CONC: 51.0 ppm H2S

H_2S AUDIT DATA

Audit (PPB)	Station (PPB)	Percent Difference
401	360	-10.2
299	261	-12.7
163	140	-14.1
75	67	-10.7
0	6	-
Slope: 0.881	Y-Intercept: 1	Corr.Coef: .9994

Dilution Chamber Flow = 182.6 cc/min

72 ppb SO2 injected through scrubber. Analyzer response = 1 ppb

SO_2 AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: Air Quality, Site 1 AUDITOR: David Gemmill

ANALYZER MFR: Meloy Labs CALIBRATOR MFR: ABB Environmental

MODEL NUMBER: SA285E CALIBRATOR S/N: 5

ANALYZER S/N: 7E034

AUDIT GAS CYL. NO: CAL 707 AUDIT GAS CONC: 103.8 ppm SO2

SO_2 AUDIT DATA

SO2 Input (PPB)	SO2 Output (PPB)	Percent Difference
416	383	-7.9
313	294	-6.1
192	183	-4.7
75	73	-2.7
0	7	-
Slope: 0.910	Y-Intercept: 7	Corr.Coef: .99990

WIND DIRECTION AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: Air Quality, Site 1 AUDITOR: David Gemmill

PARAMETER: Wind Direction SENSOR MFR: Met One

MODEL NUMBER: 024 S/N: G1260

WIND DIRECTION AUDIT DATA

Audit Point	DAS Output	Difference
360°	001°	1°
090°	091°	1°
180°	181°	1°
270°	272°	2°

NOTE: Crossarm Orientation = 1°
Data corrected for 11° WMD

WIND SPEED AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: Air Quality, Site 1 AUDITOR: David Gemmill

PARAMETER: Wind Speed SENSOR MFR: Met One

MODEL NUMBER: 014 S/N: G1255

WIND SPEED AUDIT DATA

RPM	Audit Point	Das Output	Difference
300	18.9 mph	18.9 mph	0.0 %
60	4.6 mph	4.6 mph	0.0 %
0	0.0 mph	0.0 mph	0.0 mph

TEMPERATURE AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: Air Quality, Site 1 AUDITOR: David Gemmill

PARAMETER: Temperature SENSOR MFR: Met One

MODEL NUMBER: 060 S/N: None

TEMPERATURE AUDIT DATA

Audit Point	DAS Output	Difference
76.6°F	76.6°F	0.0°F

PRECIPITATION AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: Air Quality, Site 1 AUDITOR: David Gemmill

PARAMETER: Precipitation SENSOR MFR: Weathertronics

MODEL NUMBER: 6010 S/N: None

PRECIPITATION AUDIT DATA

Volume Added	Audit Point	Das Output	Difference
79.5	0.10"	0.10"	0.00

INTEGRATED SAMPLER AUDIT

Project: True Geothermal

Station: Air Quality, Site 1

Date of Audit: August 6, 1990

Time of Audit: 14:10

Auditor: David Gemmill

Sampler MFG: Measurement Tech

Serial No.: None

Temperature: 299 ^{o}K

Stn. Press: 734.6mm Hg

INTEGRATED SAMPLER AUDIT DATA

Flowmeter Setting	Audit Flow cc/min	Station Flow	Diff %
0.8	722	736	1.9
1.0	949	957	0.8
1.4	1378	1407	2.1

TSP SAMPLER AUDIT

Project: True Geothermal

Station: Air Quality, Site 1 HI-VOL NO:

Date of Audit: August 6, 1990 Audit Kit No.: D

Time of Audit: 1300 - 1340 Temperature: 299^{o}K

Auditor: David Gemmill Barometric. Pres: 734.6 mm Hg

HI-VOLUME SAMPLER DATA

Manometer Reading (" H_2O)	Uncorrected Flow Q_i from Orifice Calibration Table ("H_2O vs. Flow)	Calibration Flow * (Q_i x FCF) SCFM	Chart Reading SCFM	Diff. %
5.4	39.9	39.2	38.8	-1.0

* Flow referenced to calibration conditions

Flow Correction Factor (FCF) = $((298 \times P2)/(T2 \times 760))^{0.5}$

PM-10 SAMPLER AUDIT

Project: True Geothermal

Station: Air Quality, Site 1 HIVOL NO:

Date of Audit: August 6, 1990 Audit Kit No.: D

Time of Audit: 1300 - 1340 Temperature: 229 ^{o}K

Auditor: David Gemmill Barometric Pres.: 734 mm Hg

PM-10 SAMPLER DATA

Manometer Reading (" H_2O)	Uncorrected Flow Q_i from Orifice Calibration Table ("H_2O vs. Flow)	Calibration Flow * (Q_i x FCF) SCFM	Chart Reading SCFM	Diff. %
5.7	41.0	41.8	40.4	-3.3

* Flow referenced to Actual conditions

Flow Correction Factor (FCF) = $((T2 \times 760) / (298 \times P2))^{0.5}$

where: T_2 and P_2 are the ambient temperature and barometric pressure during the audit.
Deviation from ideal flow of 40 ACFM = 4.5%

WIND DIRECTION AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: MET, Site 2 AUDITOR: David Gemmill

PARAMETER: Wind Direction SENSOR MFR: Weathermeasure

MODEL NUMBER: W204 S/N: 2066

WIND DIRECTION AUDIT DATA

Audit Point	DAS Output	Difference
001°	360°	-1°
091°	092°	1°
181°	180°	-1°
271°	272°	1°

NOTE: Crossarm Orientation = 1°
Data corrected for 11° WMD

WIND SPEED AUDIT

DATE: August 6, 1990 PROJECT: True Geothermal

SITE: MET, Site 2 AUDITOR: David Gemmill

PARAMETER: Wind Speed SENSOR MFR: Weathermeasure

MODEL NUMBER: W203 S/N: 1256

WIND SPEED AUDIT DATA

RPM	Audit Point	Das Output	Difference
0	0.0 mph	0.0 mph	0.0 mph
60	3.5 mph	3.1 mph	-0.4 mph
300	15.2 mph	15.7 mph	3.3 %

VERTICAL WIND SPEED AUDIT

DATE: April 15, 1990 PROJECT: True Geothermal

SITE: MET, Site 2 AUDITOR: David Gemmill

PARAMETER: Vertical Wind Speed SENSOR MFR: R. M. YOUNG

WIND SPEED AUDIT DATA

RPM	Audit Point	Das Output	Difference
0	0.0 mph	0.0 mph	0.0 mph
60 cw	0.2 mph	0.2 mph	0.0 mph
60 ccw	-0.2 mph	-0.2 mph	0.0 mph
300 cw	0.8 mph	0.8 mph	0.0 mph
300 ccw	-0.8 mph	-0.8 mph	0.0 mph

APPENDIX B

STATION INSPECTION CHECKLIST

PROJECT: True Geothermal

SITE: Air Quality, Site 1 DATE: August 6 1990

Auditor: David Gemmill

	YES	NO
1. Is the shelter secured when unattended?	Y	
2. Is the equipment power supply regulated?	Y	
3. Is heating and air conditioning adequate?	Y	
4. Is the station kept between 22°C and 25°C?	Y	
5. Is the station clean and orderly?	Y	
6. Are all gas cylinders properly secured?	Y	
7. Is the sample intake system glass or Teflon? constructed of stainless steel		N
8. Is the sample intake system clean?	(Unknown)	
9. Does the sample intake system meet all siting criteria?	Y	
10. Is the station adequately lighted?	Y	
11. Is there an up to date and legible station log?	Y	
12. Is there a stripchart or hardcopy backup to the data acquisition system?		N
13. Does the station have a complete set of instrument manuals?	Y	
14. Does the site operator complete a site checklist at each visit?	Y	
15. Is the site visited at least every 3 days?	Y	

COMMENTS: Intake manifold is stainless steel

STATION INSPECTION CHECKLIST

PROJECT: True Geothermal

SITE: Met, Site 2 DATE: August 6, 1990

Auditor: David Gemmill

	YES	NO
1. Is the shelter secured when unattended?	Y	
2. Is the equipment power supply regulated?	Y	
3. Is heating and air conditioning adequate?	NA	
4. Is the station kept between 22°C and 25°C?	NA	
5. Is the station clean and orderly?	Y	
6. Are all gas cylinders properly secured?	NA	
7. Is the sample intake system glass or Teflon?	NA	
8. Is the sample intake system clean?	NA	
9. Does the sample intake system meet all siting criteria?	NA	
10. Is the station adequately lighted?	NA	
11. Is there an up to date and legible station log?	Y	
12. Is there a stripchart or hardcopy backup to the data acquisition system?		N
13. Does the station have a complete set of instrument manuals?		N
14. Does the site operator complete a site checklist at each visit?	Y	
15. Is the site visited at least every 3 days?	Y	

COMMENTS: The MET site is a remote solar/battery powered station. Manuals for the equipment are kept at the air quality station (Site 1).

MEASUREMENT TECHNOLOGIES

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